

Problem Solving Assessment

Wendy Adams

UNIVERSITY of
NORTHERN COLORADO



Bringing Education to Life





Carl Wieman,
Stanford University



University of Colorado,
Boulder

Introduction



- **Problem solving is arguably the most important skill a physicist can have**
- **In spite of extensive research, very little progress has been made on how best to measure it and teach it.**
- **Other aspects of physics learning has seen great advances in the teaching and the measurement of learning.**

What makes a good problem solver?

Problem Solving:

"Problem solving is cognitive processing directed at achieving a goal when no solution method is obvious to the problem solver." (Mayer, 1992)

- Definition based on the solver.

Hypothesis

- **Difference between the complexity of the subject and the simplicity of the measurement tools.**
 - **Usually all that can be measured is whether the person can solve the problem or not.**
- **Provides**
 - **no insight as to what learner needs to do to improve, and**
 - **no guidance to the teacher as to how to help them.**

Hypothesis

- **Delineate the skills that a person uses when solving problems.**
- **Measure each “sub-skill”**

Simple enough....

Physics gets in the way!

- Maybe someone is a superb problem solver but they've never learned about angular momentum.
- Maybe they've learned an algorithm for solving similar problems and simply follow it.

Expert Problem Solving?

1. Draw picture, 2. Describe physics principles, 3. Identify equation, 4. Do math, and 5. Check answer

“Problem solving is cognitive processing directed at achieving a goal when no solution method is obvious to the problem solver.”

(Mayer, 1992)

Only when the solver already knows how to do that type of “problem” – so it’s not Problem Solving!

Expert Problem Solving?

- Schoenfeld (1992) - math professor vs. students
- Wineburg (1998)- history professor vs. students
- Sing (2005) – When physical intuition fails

What did they do?

- Visualize the problem
- Monitor their own progress
- Connect steps and pieces
- Estimation
- Content knowledge

Problem Solving Sub-skills

Anything that can affect the subject's ability to solve the problem.

'Addition'

'Connects steps and Pieces'

'Wants to succeed on "test"'

Problem Solving Assessment



- How can **physics - free** measurements be made?
- Study a wide range of people, solving complex problems
 - Specific failures show specific sub-skills.

PSSA - Problem Solving skill Spectra Analysis

- **Base problem from the Jasper Woodbury Series***

- Story opens with Larry teaching Emily how to fly his ultra-light plane.
- Jasper tells Emily and Larry about camping trip at Boone's Meadow 5 miles in.
- Jasper finds wounded Eagle
- Emily has complicated problem of planning best transportation considering route, payload, mileage and timing.
- The Solver is required to help Emily plan the rescue.



*<http://peabody.vanderbilt.edu/projects/funded/jasper/>

PSSA – Problem Solving skill **Spectra Analysis**



- **Two scripted “interns” solve the problem while the subject solves the problem.** (adds task of analyzing interns as well)

Sample

7. How confident are you about your answer?

- a. Positive**
- b. Pretty sure**
- c. Think it's close**
- d. Not sure at all**



Do you think that means we have to count the gas in the tanks as part of the payload or maybe it only counts extra fuel that you take along?

Sara considers this for awhile.

That seems strange but he did say the payload includes fuel so I think we should count that. What does a full tank of gas weigh?



How should I know? It held 5 gallons, does that help?

8. Do you know what the gas weighs or how they could figure this out?

PSSA – Problem Solving skill Spectra Analysis



- **Written instrument takes about 1 hour**
- **It is a “problem” regardless of your content expertise.**
- **Embedded data design** - Free of discipline specific content.
- **Identifies a student’s problem solving *fingerprint* or *spectra of sub-skills*.**
 - **Strengths as well as weaknesses.**

Scripted Problem Solving

- Questions have been placed at crucial points asking the solver to provide
 - their opinion on how the problem solving process is progressing
 - bits of factual knowledge, planning, procedures, calculations, reflections and analysis of the two scripted intern's problem solving skills.

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Scripted Problem Solving

- Unravels the sub-skills from the whole – reveals a person's Spectrum of problem solving sub-skills

Methodology

- **30 individual interviews**
- **14 paper and pencil versions graded**
- **List of 44 sub-skills identified in 3 major categories**

Categorization of Sub-skills

Knowledge – have*	Beliefs, Expectations & Motivation	Processes – do*
<ul style="list-style-type: none">• Addition/ Subtraction• Algebra• Number Sense• Knowledge of own strengths	<ul style="list-style-type: none">• Wants to solve the problem for self• Careful/Thorough	<ul style="list-style-type: none">• Planning (What)• Connects steps and Pieces• Meta-processing

Is it Valid?

How do we know PSSA tells us anything about how students solve science problems?

...Physics in particular?

Physics Instructor

- Compared PSSA interview results to faculty evaluation of students strengths and weaknesses
- Found evaluation matched with PSSA results providing more detail and explanation for observed student behavior.

Mechanics Problem

Mechanics problem solving compared to PSSA paper and pencil results. - 5 students.

Given height of the pyramid, dimensions of a block, horsepower of a man, time allotted to build, How many men were required to build the Great Pyramid of Giza?



University of Maryland Physics Education Research Group (2002).
Activity-Based Physics (ABP) Alternative Homework Assignments.
<http://www.physics.umd.edu/perg/abp/aha/index.html>

Results



- Pencil and paper PSSA graded blind
- 3 point scale used for grading.

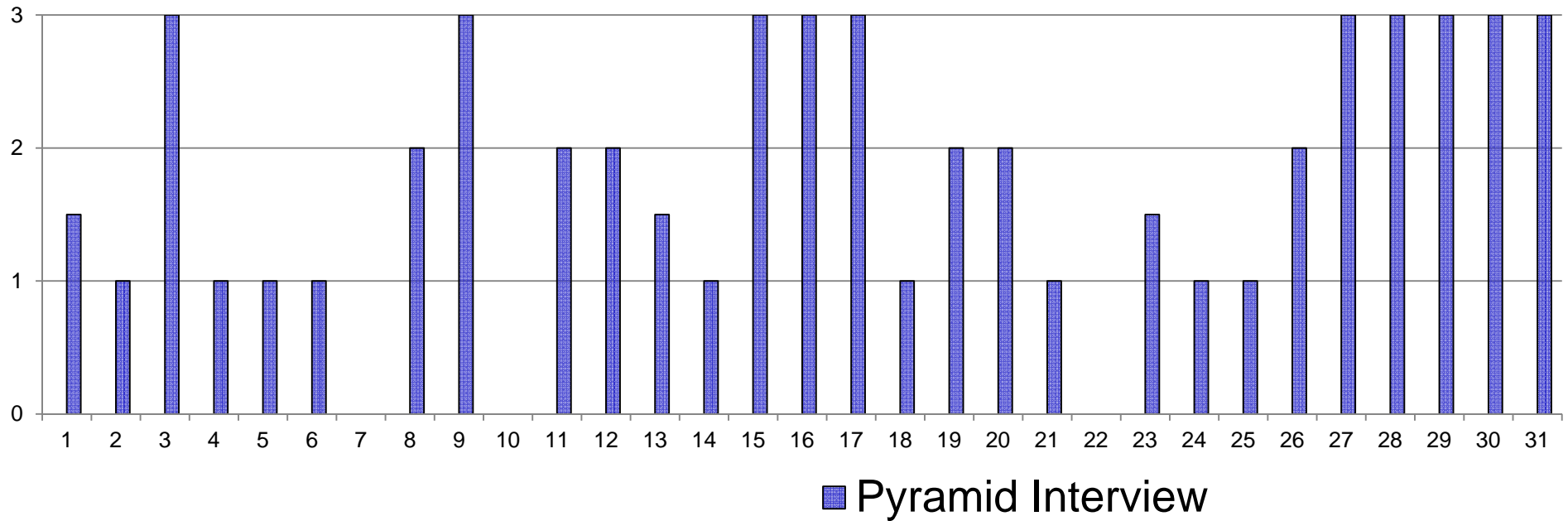
*All students easily identified and
matched up!*

Pyramid interview results



3 – point scale

Karin

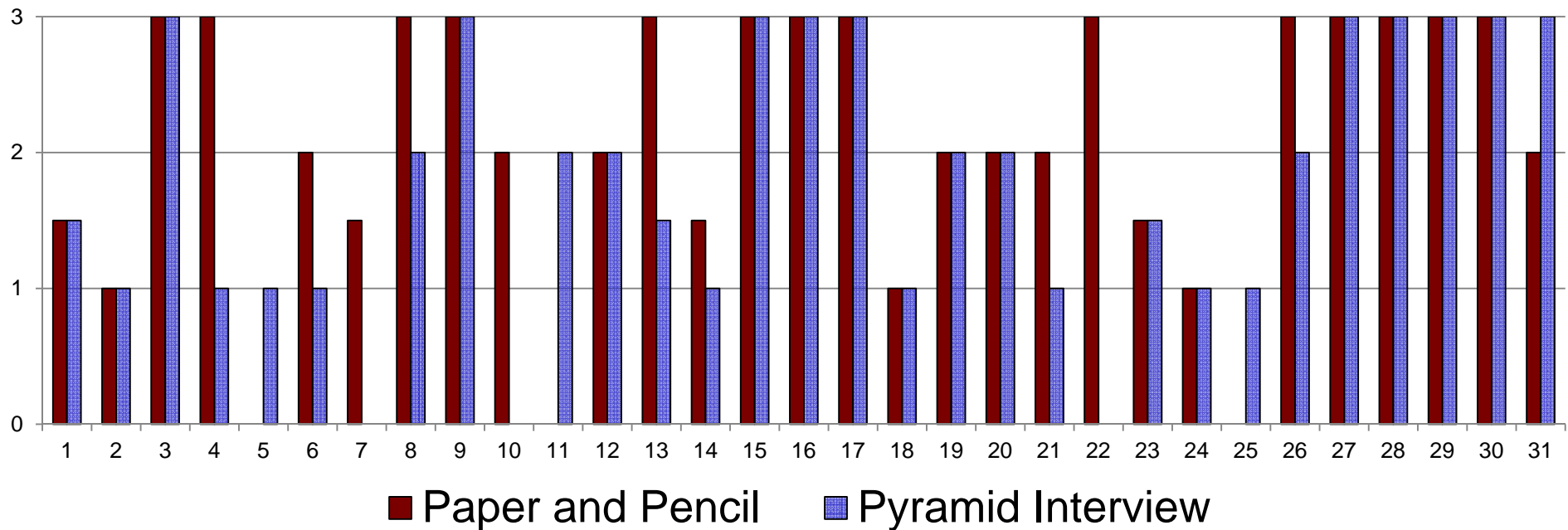


Pyramid interview w/ PSSA paper and pencil

3-point scale



Karin



Pyramid of Giza Comparison

Spectrum

Pyramid

Quantum Mechanics

Quantum Mechanics problem solving compared to PSSA results for 5 students.

- Independent interviewer scored physics and Engineering students while solving a series of Quantum Mechanics' problems biweekly interviews conducted all semester.
- I interviewed these same students solving the PSSA 6 months to a 1 year after the course.

Quantum Mechanics

Suppose you are shooting photons at a screen one at a time and you see a dot appear on the screen as in the picture to the right. Where was that photon the instant before it hit the screen?



Example Data

Quantum Mechanics Interviewer:

“she seemed to view learning [as] how to accept every weird thing we told her... she thought the first step was to accept things and the second step was to try to understand them. She always rethought her ideas when another student suggested something, although she maintained enough skepticism to recognize that other students were often wrong.”

Problem Solving Interviewer:

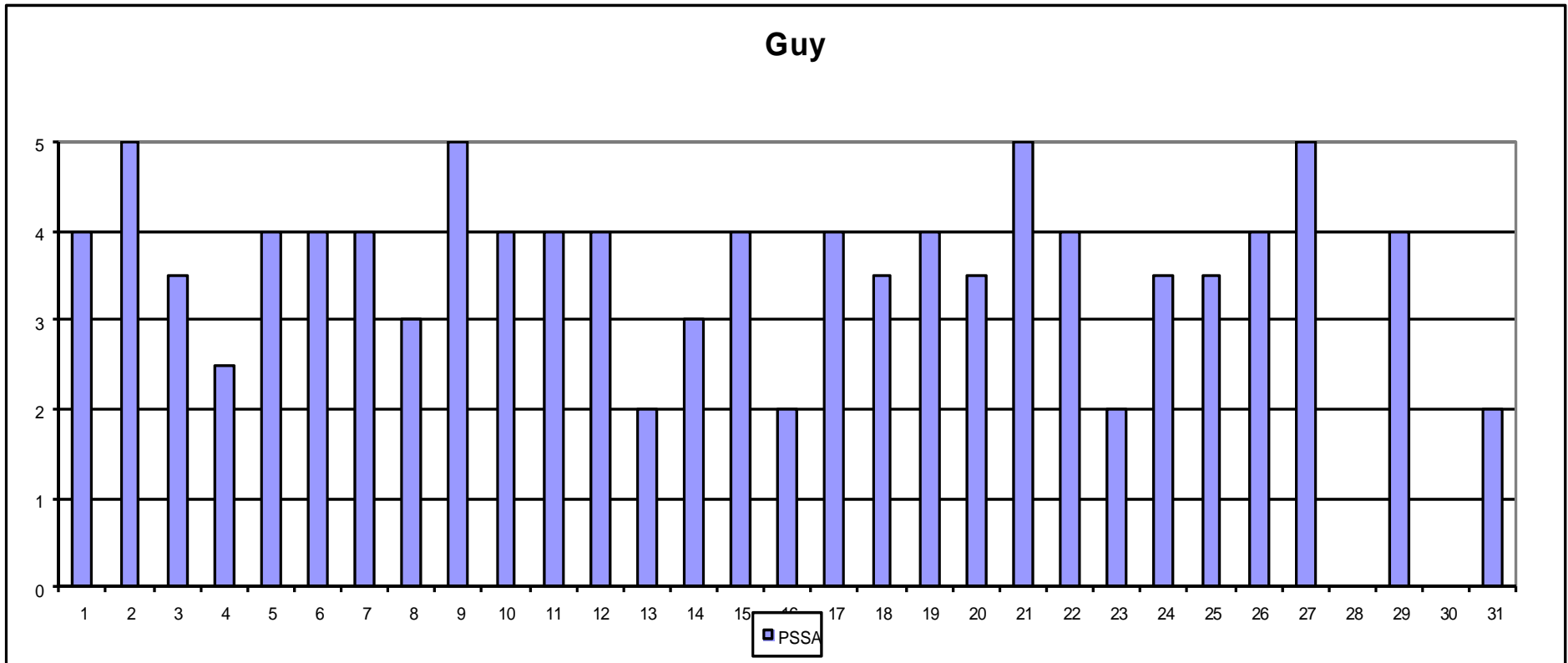
“Always had a knee jerk response which was not always good but then on her own she considers carefully and comes up with the right answer. ...she’ll consider whatever is thrown out there, decisions are based on the most logical answer. If a suggestion does not make sense after careful consideration, she holds onto her beliefs. Very reliable”

Results

5-point scale



PSSA
only



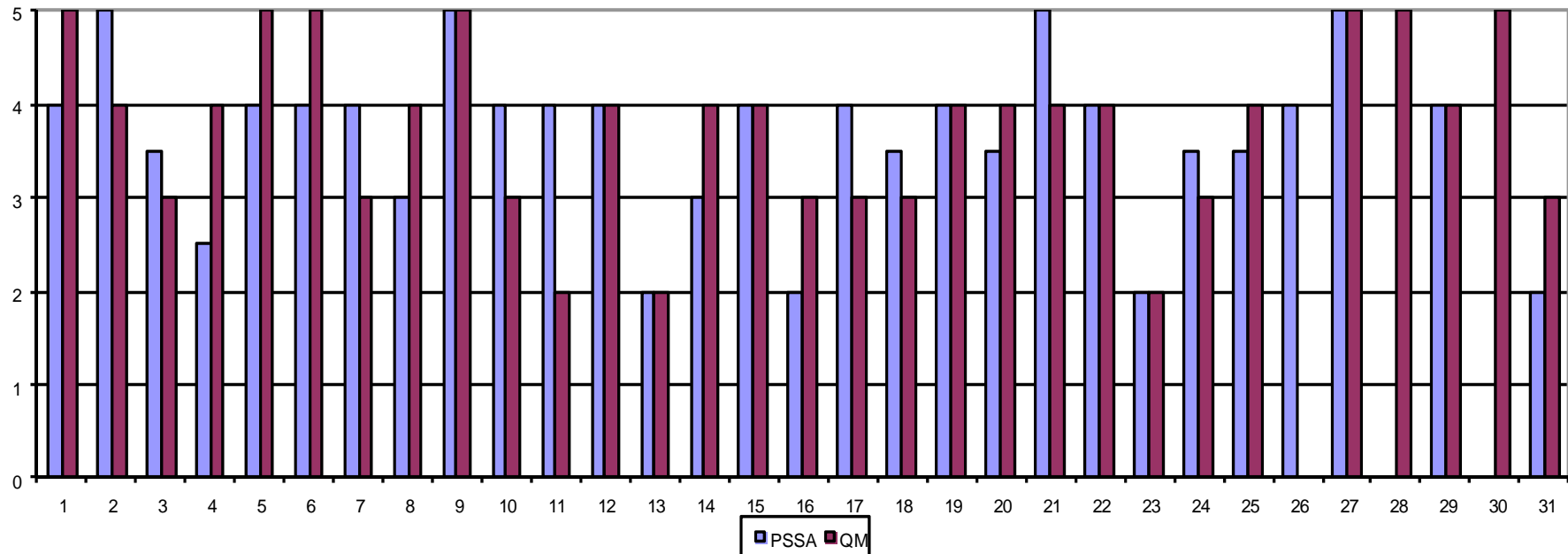
Results

5-point scale



PSSA
with
Quantum
Mechanics

Guy

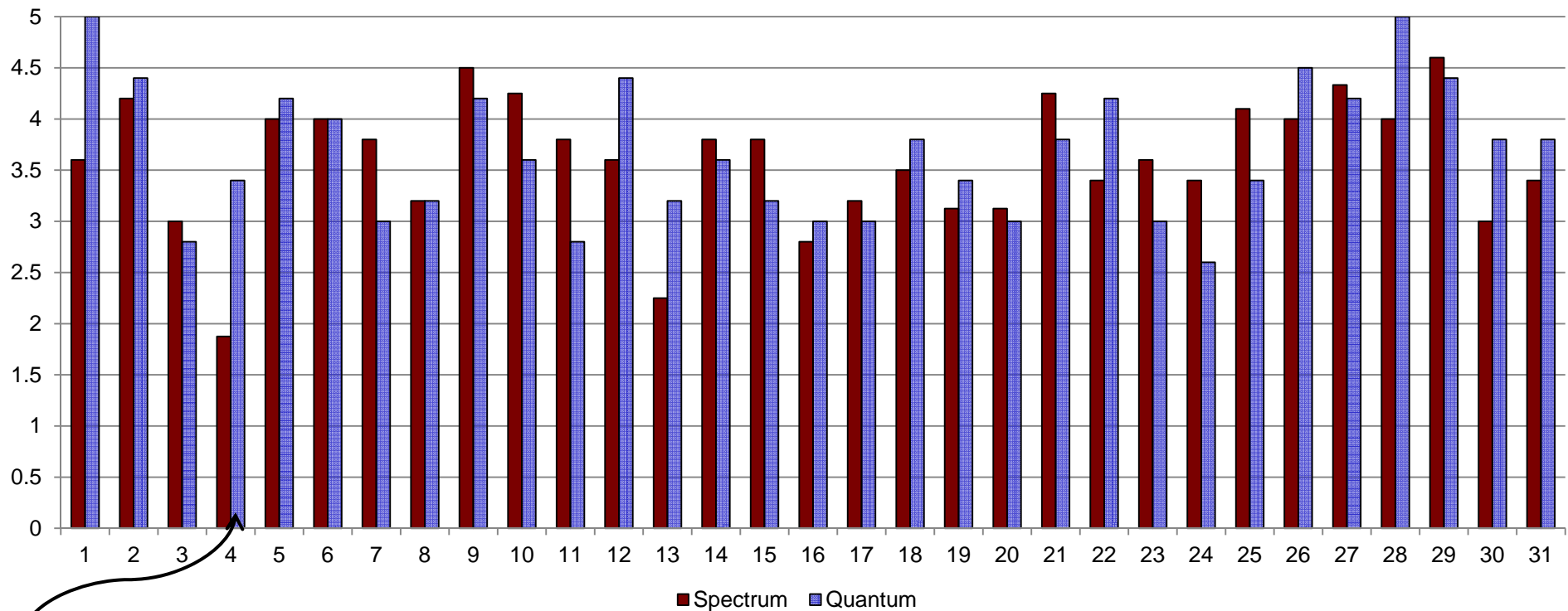


PSSA interview compared to Quantum Interview

88.5 % of scores agreed within 1 and

98.4% agreed within 2.

All Students (5)

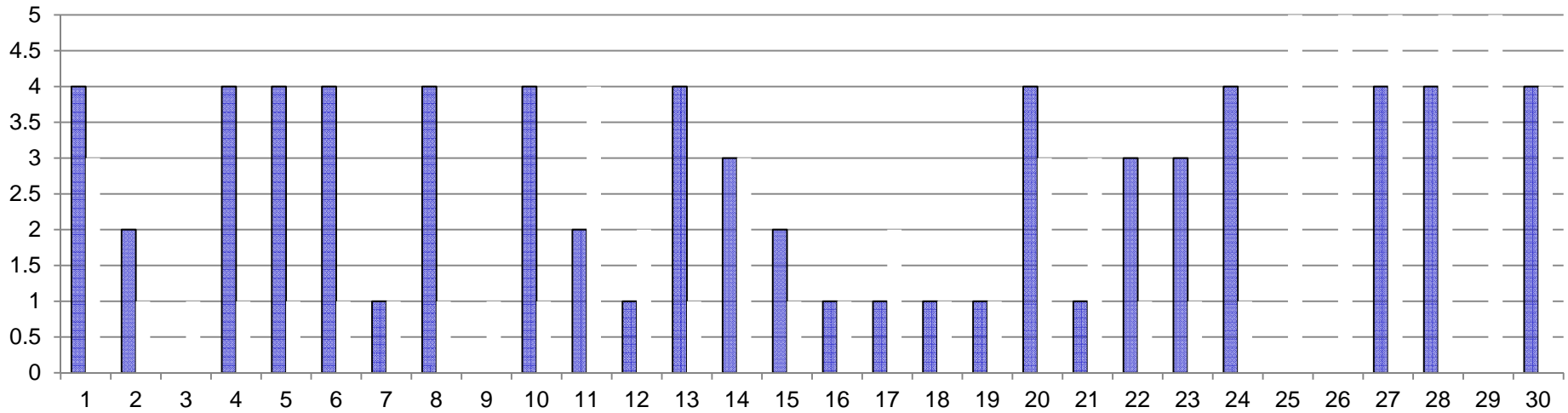


Acquires information 1st time through

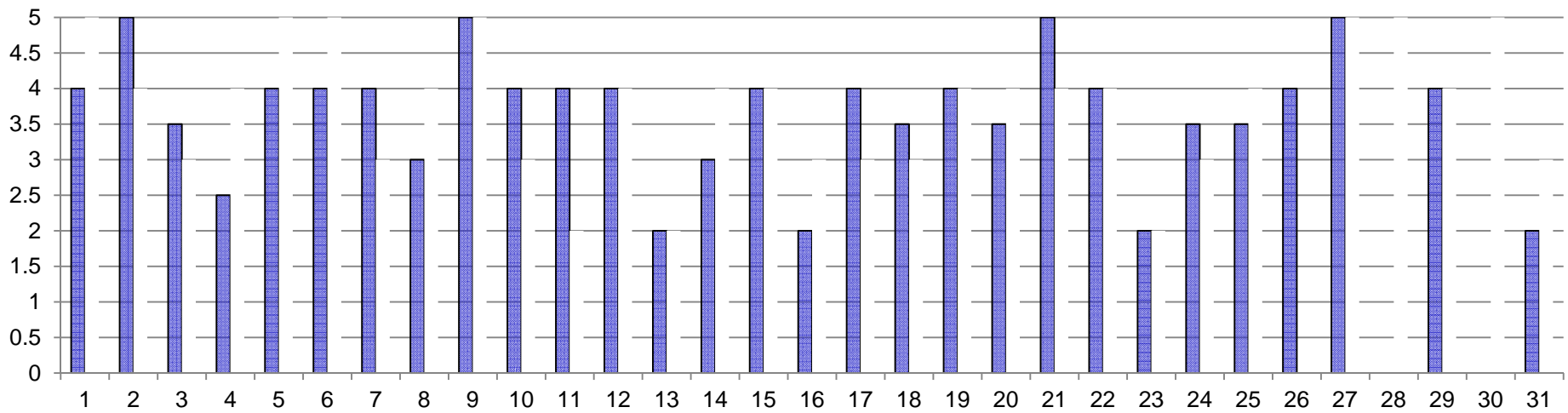
Quantum Mechanics comp.	
Spectrum	Quantum
Spatial - mapping	Did not score skills missing from the rubric
Previously known facts	
Number Sense	
Estimation	
Interested in the context of the problem	
Enjoyed Analyzing Interns	
Ability to analyze interns	
Careful/Thorough	
Judgment of importance of number values (is it material)	

Very different spectra of sub-skills

Rick



Guy



Physicists vs. Elementary Ed Majors

	Common Strengths	Common Weakness
Physics & Engineering Students	<i>Math - equation formation (4.3), Math - number sense (4), planning (4), creativity (3.8) and judgment (3.8)</i>	
Pre-Service Elementary Teachers		

Typical Problems



Typical homework problems require:

- Knowledge of the content (**Newton's Laws, algebra, ...**)
- **Remember** what s/he has calculated or reasoned
- **Wants to solve the problem** (for self, for grade, ...)

...do not require:

- **Acquiring information 1st time through**
 - quite important in real life but almost never required in school.
- **Visualize the Problem**
 - Told to draw a picture
 - meaningless exercise when not required for solution

Results

- **Itemization of sub-skills:** knowledge, processes and beliefs, expectations & motivations
- **Students bring the same skill set to very different types of problem solving.**
 - Trip Planning
 - Physics problems in general
 - A mechanics Problem
 - Quantum Mechanics Problems
- **Problem Solving skill Spectra Analysis - PSSA**



Complete listing of sub-skills:

<http://www.unco.edu/nhs/physics/faculty/adams/Research.htm>